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ENERGY IDEAS

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ENERGY MANAGEMENT AND CONSERVATION PROGRAMS

North Dakota State University Fargo, North Dakota 58105

North Dakota Tractor Use Study

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Estimates of fuel requirements are necessary for good management in selecting and operating farm machinery. If individual fuel records are available, they should be used. If specific records are unavailable, the average fuel use values in this publication can serve as an estimate. Fuel use records, kept by farmers through North Dakota over a three-year period, provide the data for this report. All tractors in the study were diesel powered.

Besides identifying average fuel use, other objectives of this study included making field comparisons of fuel use and capacity between two-wheel drive (2-WD) and four-wheel drive (4-WD) tractors and identifying ways to reduce fuel use.

FUEL EFFICIENCY RANGE

Fuel consumption varies considerably among farms. For instance, the average fuel consumption for chisel plowing recorded by individual farmers ranged from a high of 1.9 gallons per acre to a low of 0.5 gallons per acre. The fuel consumption range and average for other field operations is shown in Table 1.

The average fuel consumption rates can be used as an estimate if specific values are unavailable from individual records. A farmer whose fuel consumption rates fall in the low-to-average category shown here may conclude field operations are conducted efficiently. Consumption rates in the average-to-high range are an indication to look for reasons why. High fuel consumption rates may be the result of high yields in the case of harvesting operations or because of extreme conditions when tilling, such as plowing sod.

Table 1. Fuel Use Range for Field Operations.

Operation	gallons per acre 2-WD			4-WD		
	Low	Avg.	High	Low	Avg.	High
Tillage:						
Moldboard Plowing	1.2	1.6	3.1	.9	1.6	2.4
Discing	.4	.9	1.8	.5	.8	1.1
Chisel Plowing	.5	.8	1.9	.5	.8	1.4
Cultivating	.2	.6	1.2	.3	.6	1.0
Harrowing	.1	.2	.6	.2	.2	.8
Applying Anhydrous	.2	.5	.9	.3	.6	1.0
Cultivate Row Crops	.3	.4	.7			
Multiweeder	.4	.5	.6	.5	.6	.7
Rod Weeder	.3	.5	.5	.3	.4	.6
Surflex Tiller	.6	.6	.6			
Seeding:						
Drilling	.3	.5	1.1	.3	.5	.8
Planting	.2	.3	.5			
Combination Operations:						
Drill Combination	.4	.8	1.1	.5	.8	1.0
Plow Packer Drill	1.3	1.7	2.2	1.8	1.8	1.8
Plant Combination	.6	.6	.6			
Harvesting:						
Swathing	.3	.3	.4			
Combining	.5	1.1	1.3			
Forage Harvesting	1.2	1.5	2.2			
Baling	.3	.7	.9			

STATE AVERAGES

Statewide average fuel use rates in gallons per acre and in gallons per hour for various field operations are listed in Table 2. The average field capacity in acres per hour, as well as average working depths and travel speeds, is also given. The data average all types of soil, operating conditions and makes and models of equipment. While data from individual pieces of equipment vary, the information in Table 2 is useful for making relative comparisons.

4.3
9
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Table 2. State Averages for Field Operations by Tractor Type.

	Moldboard Plowing		Discing		Chisel Plowing		Cultivating		Drilling		Harrowing	
	2WD	4WD	2WD	4WD	2WD	4WD	2WD	4WD	2WD	4WD	2WD	4WD
Gallons/Acre	1.6	1.6	.9	.8	.8	.8	.6	.6	.5	.5	.2	.2
Gallons/Hour	4.7	10.9	5.9	9.3	6.1	10.0	6.0	10.1	5.2	7.9	5.0	7.1
Acres/Hour	3.2	7.1	7.1	12.9	8.6	13.3	10.3	17.4	11.9	17.4	25.6	34.1
Depth (in.)	6.4	7.0	4.3	4.2	5.4	5.8	4.5	4.4	2.2	2.4	2.1	2.0
MPH	4.9	5.3	5.6	5.4	5.3	5.4	5.8	6.0	6.1	6.1	6.7	7.1

	Cultivate Row Crop		Multiweeder		Rod Weeder		Surflex Tiller		Swathing		Combining	
	2WD	4WD	2WD	4WD	2WD	4WD	2WD	4WD	2WD	4WD	2WD	4WD
Gallons/Acre	.4	—	.5	.6	.5	.4	.6	—	.3	—	1.1	—
Gallons/Hour	3.6	—	6.7	10.8	5.1	8.4	3.4	—	3.6	—	3.7	—
Acres/Hour	10.5	—	12.7	18.9	11.2	23.8	5.8	—	11.7	—	3.6	—
Depth (in.)	2.5	—	3.0	3.0	2.8	3.0	3.5	—	—	—	—	—
MPH	4.7	—	6.0	5.8	5.3	6.2	6.2	—	5.1	—	2.2	—

	Raking		Stacking		Forage Harvesting		Baling		Hay Conditioner		Fertilizer Spreading	
	2WD	4WD	2WD	4WD	2WD	4WD	2WD	4WD	2WD	4WD	2WD	4WD
Gallons/Acre	.2	—	.6	—	1.5	—	.7	—	.5	—	.2	—
Gallons/Hour	2.1	—	3.2	—	3.8	—	2.8	—	2.2	—	4.4	—
Acres/Hour	9.1	—	5.7	—	3.0	—	4.7	—	4.9	—	15.6	—
Depth (in.)	—	—	—	—	—	—	—	—	—	—	—	—
MPH	6.5	—	5.5	—	4.1	—	4.9	—	4.6	—	10.0	—

	Anhydrous Application		Drill Combination		Plow Packer Drill		Planting (Row Crops)		Plant Combination		Chemical Application	
	2WD	4WD	2WD	4WD	2WD	4WD	2WD	4WD	2WD	4WD	2WD	4WD
Gallons/Acre	.5	.6	.8	.8	1.7	1.8	.3	—	.6	—	.3	.3
Gallons/Hour	5.7	9.2	4.9	9.2	4.7	7.9	3.4	—	4.7	—	4.4	11.7
Acres/Hour	13.4	17.2	6.7	11.9	2.8	4.6	10.4	—	8.3	—	14.5	30.1
Depth (in.)	4.8	5.7	3.2	3.6	6.3	7.0	2.4	—	—	—	4.0	3.1
MPH	5.2	5.6	5.6	5.7	5.4	5.1	5.3	—	4.8	—	5.2	6.9

DISTRICT COMPARISONS

To localize information, the state was divided into four districts (Figure 1). Fuel consumption averages were generally higher in the Red River Valley, which may be the result of the heavier soil in eastern North Dakota or different operating conditions.

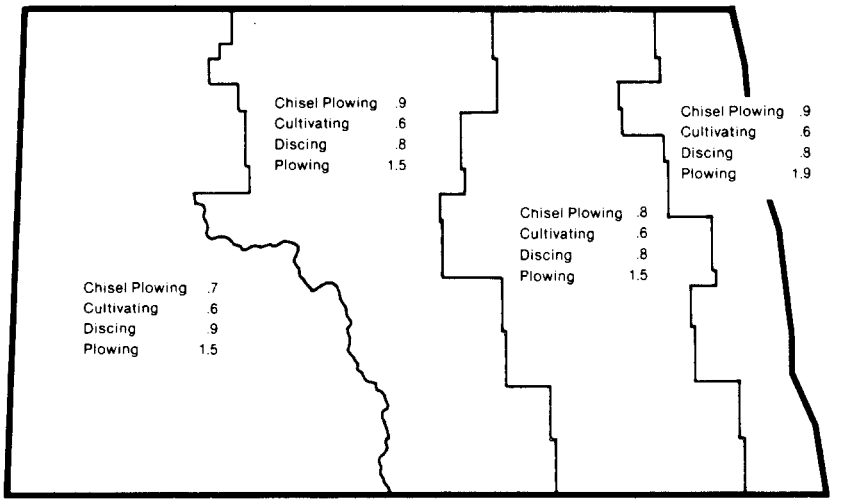


Figure 1. Fuel Efficiency Average by District, All Data (Gallons per Acre)

TRACTOR COMPARISON

When pulling full loads, large tractors use more gallons per hour than small tractors. However, they should also be covering more acres. Use gallons per acre when comparing different sized tractors. As shown in Table 3, 4-WD tractors averaged 69 percent more fuel on a gallon-per-hour basis than 2-WD tractors. However, 4-WD tractors also averaged 68 percent more acres per hour. This table also shows there was little measured difference in fuel efficiency on a gallon-per-acre basis between 2-WD and 4-WD tractors. The main advantage of the 4-WD is increased field capacity and reduced labor requirements.

Table 3. Tractor Fuel Consumption, Field Capacity and Fuel Efficiency (2-WD vs 4-WD).

Operation	Fuel Consumption Gallons per hour 2-WD	4-WD	% increase with 4-WD	Field Capacity Acres per hour 2-WD	4-WD	% increase with 4-WD	Fuel Efficiency Gallons per acre 2-WD	4-WD
Moldboard plowing	4.7	10.9	131.9	3.2	7.1	121.9	1.6	1.6
Discing	5.9	9.3	57.6	7.1	12.9	81.7	.9	.8
Chisel plowing	6.1	10.0	63.9	8.6	13.3	54.7	.8	.8
Cultivating	6.0	10.1	68.3	10.3	17.4	68.9	.6	.6
Drilling	5.2	7.9	51.9	11.9	17.4	46.2	.5	.5
Harrowing	5.0	7.1	42.0	25.6	34.1	33.2	.2	.2
			Average Increase 69%			Average Increase 68%		

FACTORS AFFECTING FUEL CONSUMPTION

The amount of fuel per acre needed for farm operations depends on several variables, including soil type, soil moisture content, operating depth and operating speed.

Soil type — When tillage machines are operated in fine-textured soil such as clay loams, more fuel will be needed than when the machines operate at the same depth and speed in a coarser soil, such as sandy loam.

Soil moisture content — Soil moisture content has a dramatic effect on tillage properties. This effect is greater in clay loam soils than in sandy loam soils.

Depth of penetration — The deeper the tillage tool penetrates, the more fuel will be needed to perform the job, as shown in Figure 2. Information from the North Dakota Tractor Use Study indicates the fuel increase is greater with 2-WD tractors than with 4-WD tractors. This may indicate 4-WD tractors can handle heavier loads more efficiently. The increase in energy use due to increase in depth is significant in both cases.

Speed of operation — Higher travel speeds will have higher energy requirements. However, more acres will be covered in a given amount of time. Farmers in this study used less energy on a per acre basis while chisel plowing at faster speeds than when traveling slower. An explanation for this may be that tractors are better matched to the load they are pulling at faster speeds, or that operating depth decreased with speed.

Tractors operated at higher speeds (5-7 MPH) require less ballast, have lower rolling resistance, and have less strain on clutches, gears, bearings, and axles.

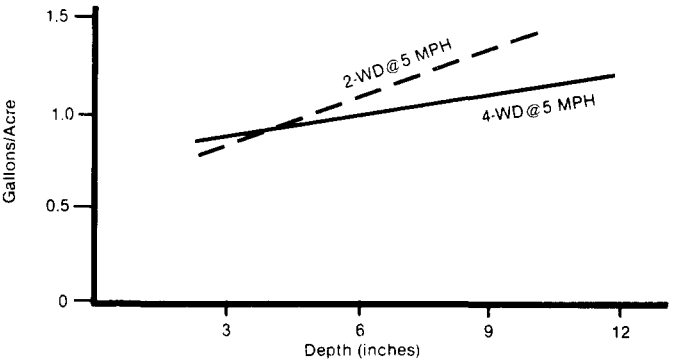


Figure 2. Effect of Depth on Gallons per Acre by Tractor Type While Chisel Plowing.

COMBINED OPERATIONS

Results show a combined seeding and cultivation operation (drill combination) requires an average of 27 percent less fuel than the two separate operations (Table 4). The same holds true when combining row crop planting with a cultivating operation (plant combination). Results indicate a 33 percent savings when combining these operations. Equal quality work must be assumed in both cases.

Pulling a plow-packer-drill is a combined operation that has been used in North Dakota for many years as a spring seeding method. Here the tilling and seeding operation is completed with one pass over the field. A low fuel requirement, 1.7 gallons per acre, does a complete job of tilling and seeding — a considerable savings when compared to plowing and seeding as separate operations.

Table 4. Energy Savings from Combined Operations.

Operation	Average gallons per acre 2-WD	4-WD
Cultivating	.6	.6
Drilling	.5	.5
TOTAL	1.1	1.1
Drill combination	.8 (27% savings)	.8 (27% savings)
Cultivating	.6	
Planting	.3	
TOTAL	.9	
Plant Combination	.6 (33% Savings)	
Moldboard Plowing	1.6	1.6
Drilling	.5	.5
TOTAL	2.1	2.1
Plow-Packer-Drill	1.7 (19% Savings)	1.8 (14% Savings)

NEBRASKA TRACTOR TEST COMPARISON

Drawbar HP tests are conducted on concrete in the Nebraska Tractor Tests. Tests are conducted at three levels — maximum pull at maximum power, 75 percent of pull at maximum power and 50 percent of pull at maximum power.

To relate the tractor performance in Nebraska tests to tractor performance in the field, the results of the 75 percent and 50 percent of pull at maximum power tests are typically used. Fuel used (in gallons per hour) by tractors while chiseling and moldboard plowing was compared to Nebraska Test fuel data. Results indicate the overall average fuel used in gallons per hour is approximately the same as that used during the 50 percent of pull at maximum power test at Nebraska. If a direct comparison is made between fuel consumption and percent load on the tractor, the results indicate that when pulling a heavy load (chisel plow, moldboard plow) around 50 percent of the tractor's maximum available drawbar power, as determined at Nebraska, is being used in the field (Figure 3).

A tractor is not expected to pull the same load in the field it can pull on concrete. References indicate it's realistic to pull loads in the field equaling 50 to 70 percent of maximum pull on concrete. Tractors in this study were shown to be loaded near the low side of that range.

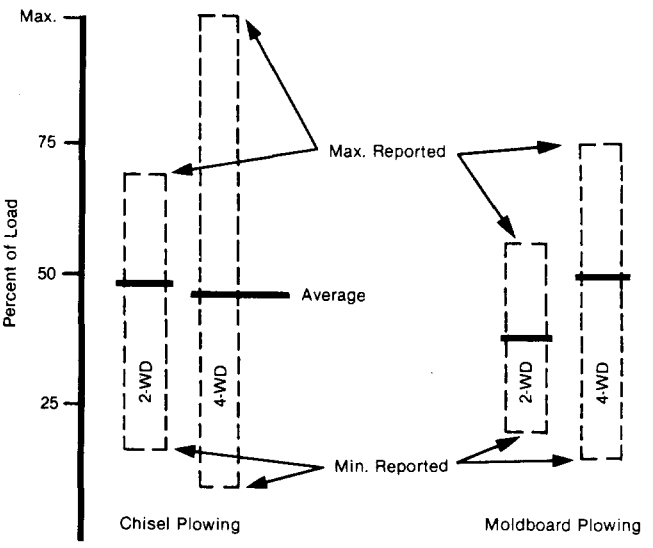
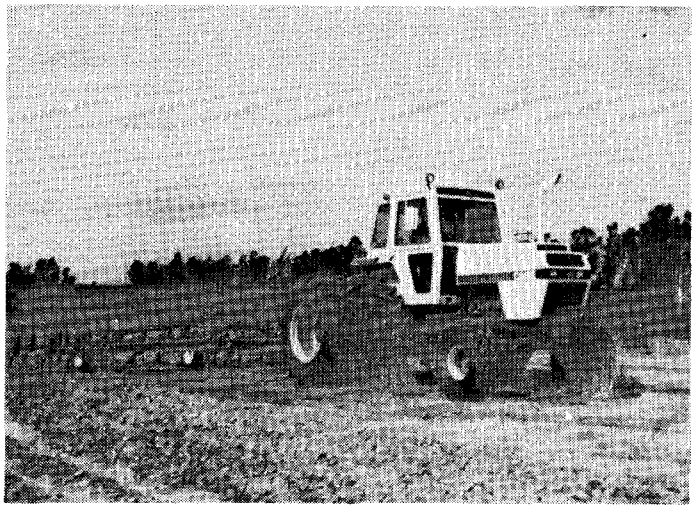


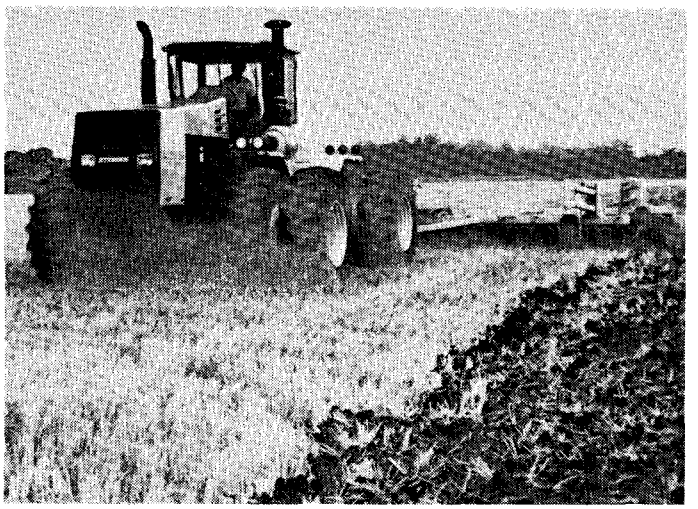
Figure 3. Percent Load while Chisel and Moldboard Plowing

BENEFITS OF FUEL RECORDS

Information from the study can be used to estimate the fuel requirements for various field operations. Keep your own records to compare to study averages. Fuel records are easy to keep. A fuel meter for each storage tank on the farm and a notebook for each tractor are needed. Important entries to make for each operation are acres, fuel used, hours, depth of tillage and speed. Benefits that can be derived from fuel use records include:

- learning fuel requirements per acre for various field operations.
- identifying the fuel requirements for producing a crop.
- identifying inefficient tractors.
- identifying inefficient operations.





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